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EXPERIMENTAL DETERMINATION OF THE HYDRODYNAMIC LOADING FUNCTION--ETC(U)
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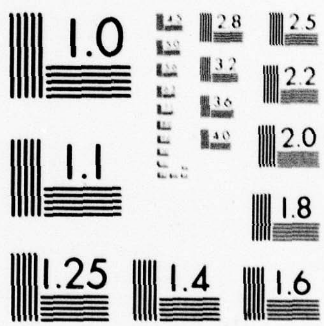

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EXPERIMENTAL DETERMINATION OF THE HYDRODYNAMIC LOADING FUNCTIONS FOR SECTIONAL-TYPE FAIRING.

by

10 C. O. Walton

12 17p.

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Experimental Determination of the Hydrodynamic Loading Functions for Sectional-Type Fairing Report 277-H-01

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The Naval Ship Research and Development Center is a U.S. Navy center for laboratory effort directed at achieving improved sea and air vehicles. It was formed in March 1967 by merging the David Taylor Model Basin at Carderock, Maryland and the Marine Engineering Laboratory at Annapolis, Maryland.

Naval Ship Research and Development Center
Washington, D.C. 20007

INTRODUCTION

The Naval Ship Research and Development Center (NSRDC) established a broad research project under the Variable Depth Sonar Program directed toward the development of improved experimental and analytical techniques for predicting the steady-state characteristics of cable-towed systems. The project consists of basin tests to ascertain the hydrodynamic loading functions of various types of faired sections and cables under steady conditions. This report deals with basin tests to determine the loading functions of a cable faired with sectional type fairing. over

The differential equations for describing mathematically the two-dimensional equilibrium configuration and forces of a cable-body system[1] were derived a number of years ago. Solutions for these equations can be obtained numerically using a digital computer[2] provided the body characteristics and cable loading functions are known. The characteristics of the towed body can either be calculated or experimentally determined using various mechanisms[3,4]. The cable loading functions are not generally known and past practice at NSRDC has been to use the loading functions proposed by different investigators[1,5,6]. Some of these functions are based on limited experimental data; but in the case of faired towcables there is considerable doubt as to whether any of the existing functions can accurately represent the loading on an arbitrary faired towcable. This doubt is borne out in the difference obtained in tangential loading of several faired shapes recently investigated[7,8,9,10].

In view of the aforementioned uncertainties, the limited experimental data on which to base loading functions, and the lack of experiments to ascertain the validity of proposed loading functions and especially on sectional fairing, the NSRDC project was established to obtain the two-dimensional steady-state hydrodynamic loading functions of a faired towcable for application to existing and future VDS systems with sectional fairing. The experimental approach consisted of towing a rigid faired-cable model in the David Taylor Model Basin at various speeds, cable angles, and model submergences and measuring the hydrodynamic force using the DTMB Cable-Fairing Dynamometer. These

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References are listed on page 15

data were then used with a curve-fitting computer program to obtain mathematical expressions for the loading functions.

This report is concerned with experiments on a sectional fairing similar to those conducted for the continuous trailing-fairing models. The report describes the subject fairing model, the towing dynamometer, the test instrumentation and test procedures; presents tabulated values and graphs of normal and tangential loading functions and drag coefficients; and provides mathematical expressions obtained for the loading functions.

DESCRIPTION OF FAIRED-CABLE MODEL

The faired-cable model consists of a simulated stranded-cable element on which 10 pieces of sectional fairing are attached. Table 1 gives the physical characteristics of the test model.

TABLE 1

Physical Characteristics of Fairing Model

Model length, inches	84.00
Section length, inches	8.25
Chord length, inches	16.50
Maximum fairing thickness, inches	2.75
Cable diameter, inches	2.40
Projected frontal area, square feet	1.60
Wetted surface area, square feet	20.42

The sectional enclosed fairing is basically a DTMB Number 7 shape as described in Reference 11 and is similar to that presently in use on the SQA-10 VDS system. A typical section, shown in Figure 1, consists of a hard plastic trailing section, a stainless steel headpiece or leading section, alinement rods and associated hardware. Each of these sections is placed over the simulated cable to form a 7-foot test model. The completed model formed an enclosed fairing model with a scalloped leading edge. The scalloped leading edge is the result of the design of the fairing for winding on a storage drum. The simulated cable, 2.4 inches in diameter, consists of twenty-four 0.25-inch-diameter copper strands with a left-hand lay joined to a seamless tube.

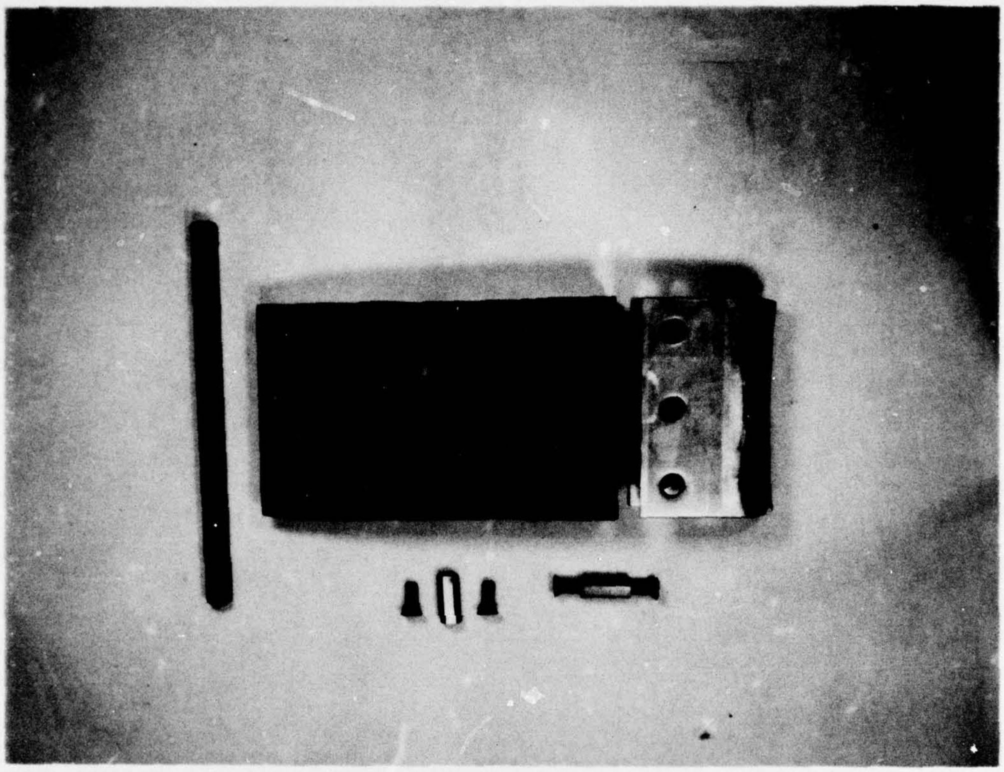

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Figure 1 - A Sectional-Type Fairing Section

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DESCRIPTION OF DYNAMOMETER AND INSTRUMENTATION

The cable-fairing dynamometer is shown in Figure 2 with the faired-cable model attached. The normal force X, lateral force Y, and tangential force Z on the model are sensed by 4-inch-cube modular force gages of the type described in Reference 3. Interchangeable gages with capacities ranging from 50 pounds to 1000 pounds are available depending on the accuracy desired. The dynamometer design limits any of the three component forces to 500 pounds or less.

The tilt-table angle is adjustable so that the cable angle φ relative to the free stream may be varied from 90 degrees to 30 degrees in 5-degree increments. The vertical position of the model and tilt table is also adjustable by means of an electric hoist so that the model submergence may be varied from 0 to 7 feet. A weight-pan system provides a means of counterbalancing the model weight on the gages at each submergence and cable angle.

Instrumentation for this test consisted of a 200-pound-capacity gage for the X force, a 1000-pound-capacity gage for the Y force, and a 50-pound capacity gage for the Z force; two integrating digital voltmeters, a scanner and a printer for processing the X and Z gage signals; and a strip chart recorder for monitoring the Y force. Carriage speed was measured using a photo-cell and gear wheel with the signal fed to an electronic counter.

TEST PROCEDURES

The model was towed in the high-speed basin of the David Taylor Model Basin from 90 degrees to 30 degrees in approximately 10-degree increments. The model submergence was varied from 31 inches to 73.5 inches in approximately 9-inch increments at towing speeds of 2, 4, and 6 knots. In addition, for a cable angle of 90 degrees, the model was towed at various speeds from 1 to 10 knots at all submergences. The X, Y, and Z forces were recorded for each test condition. The Y force measurement was used primarily as a basis for alining the model with the flow to minimize the Y force and to provide a means of monitoring lateral oscillations at various speeds.

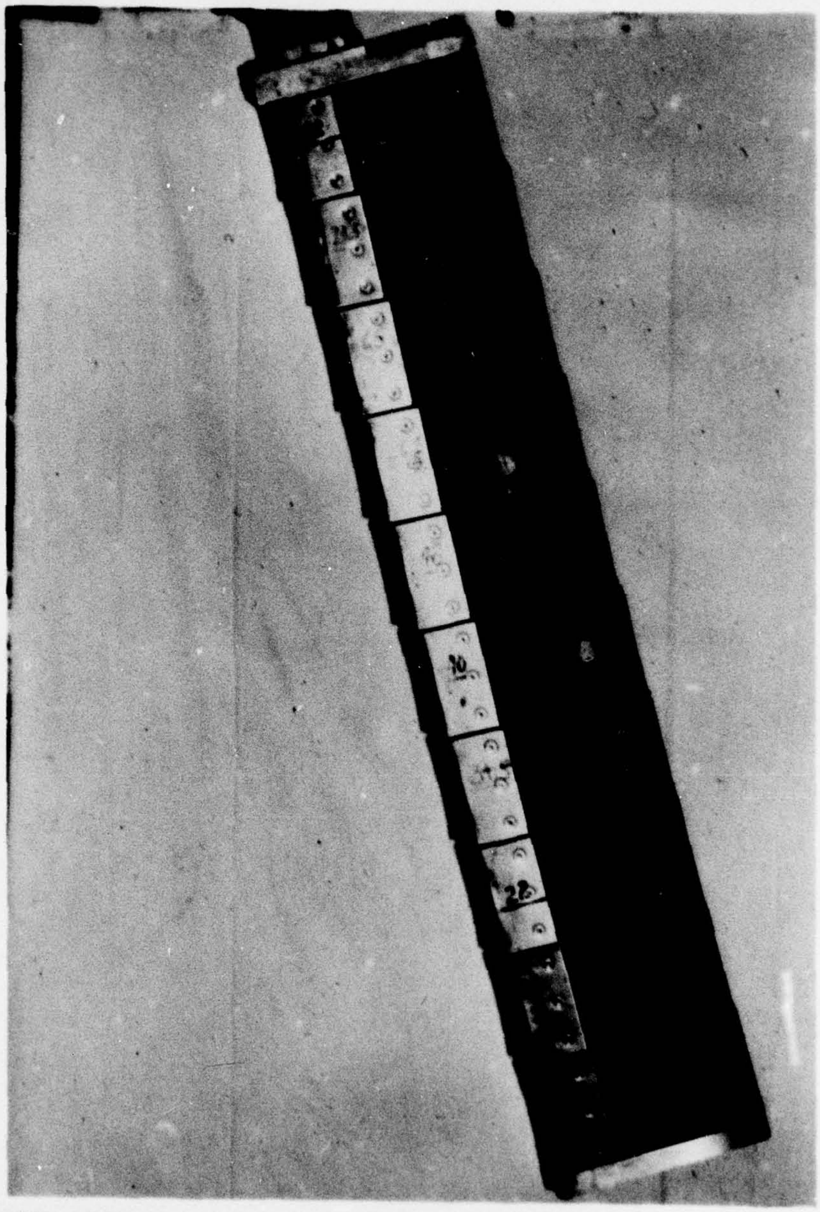

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Figure 2 - Fairing Model Attached to Dynamometer

HYDRODYNAMIC FORCES

Since the measured forces were generated by a three-dimensional model which pierced the water surface, the data contain both end effects and surface effects. The desired two-dimensional hydrodynamic forces were obtained from these data by the following analysis. The X and Z forces were plotted as a function of model submergence for each angle and speed. As model submergence increases, a length is reached after which both X and Z forces become linear functions of submergence for a given speed, i.e., end and surface effects become essentially constant. Typical plots for the X and Z force as a function of submergence for an angle of 59.9 degrees are shown in Figures 3 and 4, respectively. Slopes of the linear portion of the force-submergence curves were determined for each angle and speed and have been tabulated in Table 2. These slopes represent the two-dimensional hydrodynamic forces per unit length acting on the faired cable model.

TABLE 2

Two-Dimensional Hydrodynamic Force for an Enclosed Sectional Fairing

Cable Angle, degrees	Normal, pounds per foot			Tangential, pounds per foot		
	Speed, knots			Speed, knots		
	2	4	6	2	4	6
30.58	0.321	0.850	1.787	0.250	0.678	1.872
40.38	0.406	1.110	2.301	0.217	0.580	1.653
50.47	0.526	1.385	2.856	0.184	0.500	1.501
59.90	0.622	1.633	3.392	0.160	0.435	1.261
69.83	0.748	1.931	4.050	0.102	0.260	0.609
79.73	0.784	2.059	4.241	0.045	0.181	0.544
89.88	0.807	2.107	4.356	0	0	0

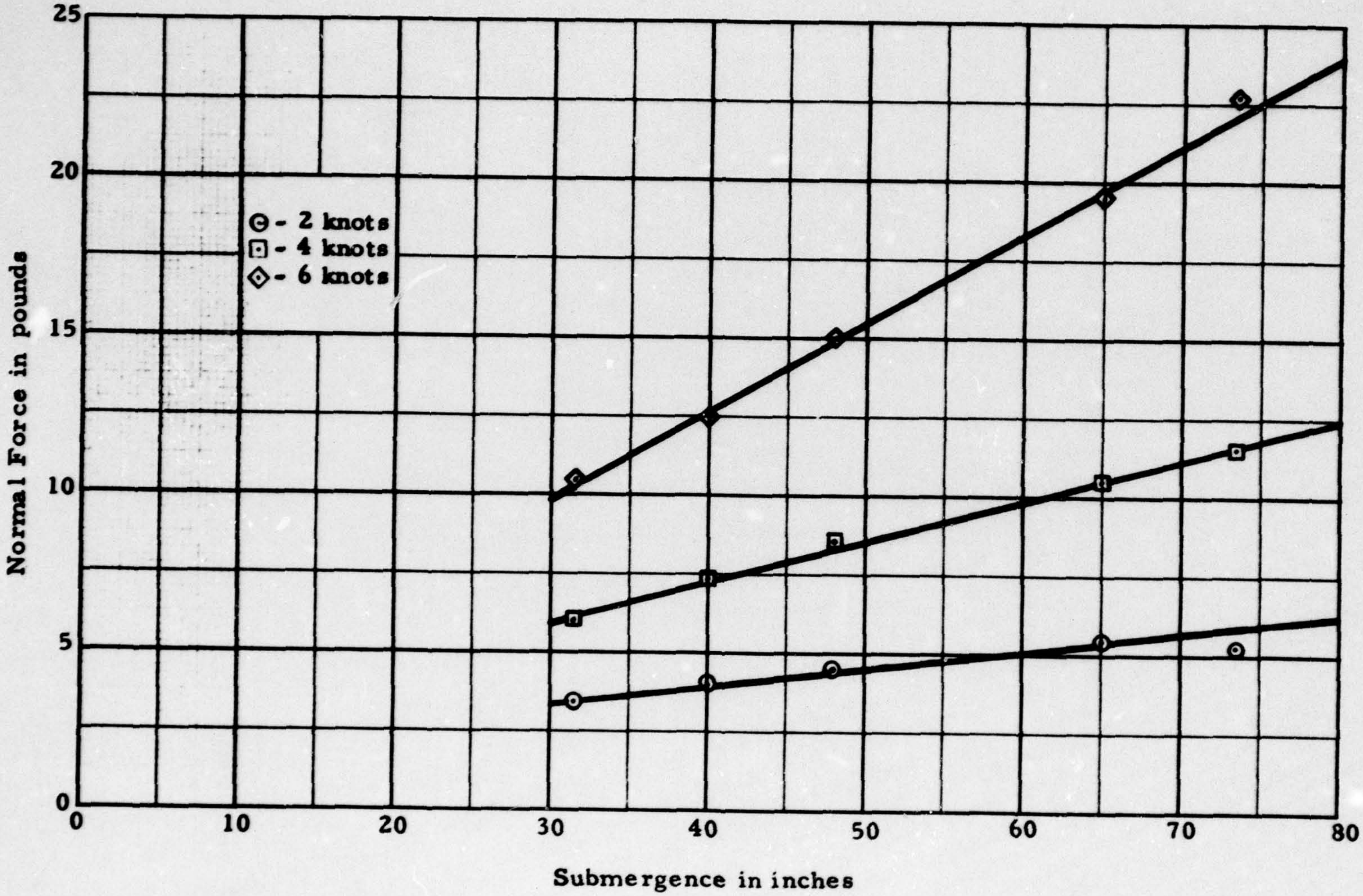

Figure 3 - Normal Force as a Function of Submergence for a Cable Angle of 59.9 Degrees

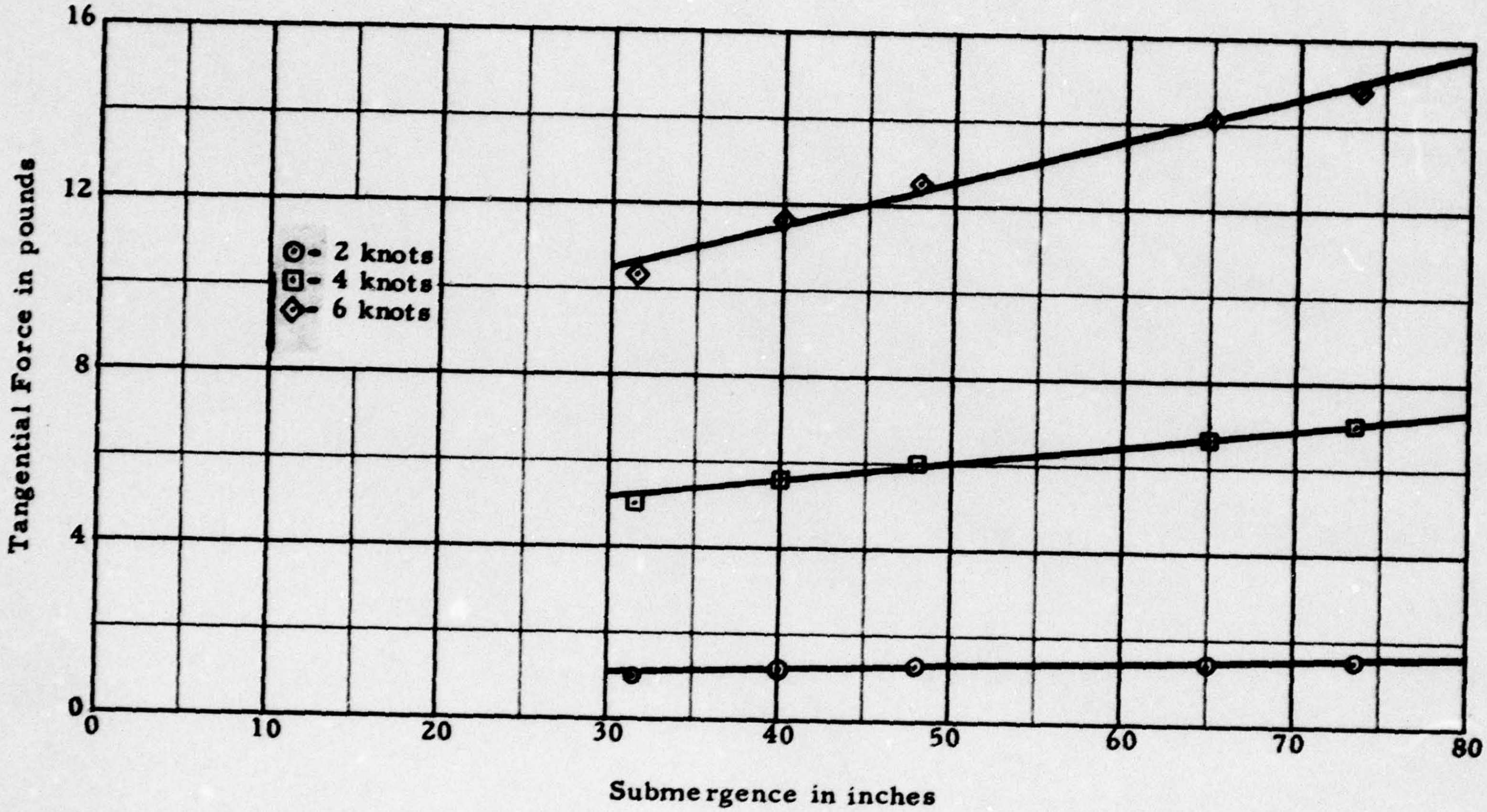

Figure 4 - Tangential Force as a Function of Submergence for a Cable Angle of 59.9 Degrees

HYDRODYNAMIC LOADING FUNCTIONS

The hydrodynamic loading functions are defined as the ratio of the steady-state, two-dimensional, hydrodynamic forces acting on an element of cable at an angle φ to the free stream to the force when the element is normal to the free stream (φ = 90 degrees). For a given faired-cable geometry and speed, these loading functions are dependent only on the cable angle.

The normal and tangential loading functions were determined using the slopes of Table 2. The slopes at each cable angle were divided by the slope of the normal-force curve for φ = 90 degrees to obtain the loading values for each angle and speed and the resulting values are tabulated in Table 3.

TABLE 3

Values of Normal and Tangential Loading Functions

Cable Angle, degrees	Normal, X/X_{90}			Tangential, Z/X_{90}		
	Speed, knots			Speed, knots		
	2	4	6	2	4	6
30.58	0.400	0.405	0.409	0.313	0.323	0.420
40.38	0.500	0.525	0.520	0.271	0.276	0.380
50.47	0.650	0.657	0.655	0.200	0.207	0.290
59.90	0.775	0.776	0.779	0.200	0.207	0.290
69.83	0.925	0.920	0.925	0.125	0.128	0.140
79.73	0.975	0.976	0.975	0.056	0.086	0.125
89.88	1.000	1.000	1.000	0	0	0

A curve-fitting process was performed on each set of values in Table 3 to obtain mathematical expressions for the loading functions. The process consisted of generating a group of least-squares curves for each set of loading values using the BVPDE3 program and selected combinations of terms in the trigonometric series,

$$A_0 + A_1 \cos \varphi + B_1 \sin \varphi + A_2 \cos 2\varphi + B_2 \sin 2\varphi$$

for which the loading boundary conditions are satisfied. Using the CMPFN2

program, curves in each group were compared with the data to determine the best form for each loading function. The resulting mathematical expressions for the loading functions, neglecting any effect of Reynolds number, are

$$\Lambda(\varphi) = -1.5716 + 1.7367 \cos\varphi + 2.4065 \sin\varphi - 0.1651 \cos 2\varphi - 0.7808 \sin 2\varphi \quad [1]$$

and

$$\Gamma(\varphi) = -0.1158 + 0.4641 \cos\varphi + 0.1158 \sin\varphi \quad [2]$$

where Λ and Γ are the normal (X/X_{90}) and tangential (Z/X_{90}) loading functions, respectively. The foregoing expressions and the attendant data from Table 3 are plotted in Figures 5 and 6. The prescribed boundary conditions are

$$\Lambda(0) = 0, \quad \Lambda(90) = 1, \quad \text{and} \quad \Gamma(90) = 0 \quad [3]$$

On the tangential loading function shown in Figure 6, there appears to be some effect due to Reynolds number. However, the effect with this sectional fairing is the reverse of that shown in Table 2 of Reference 8.

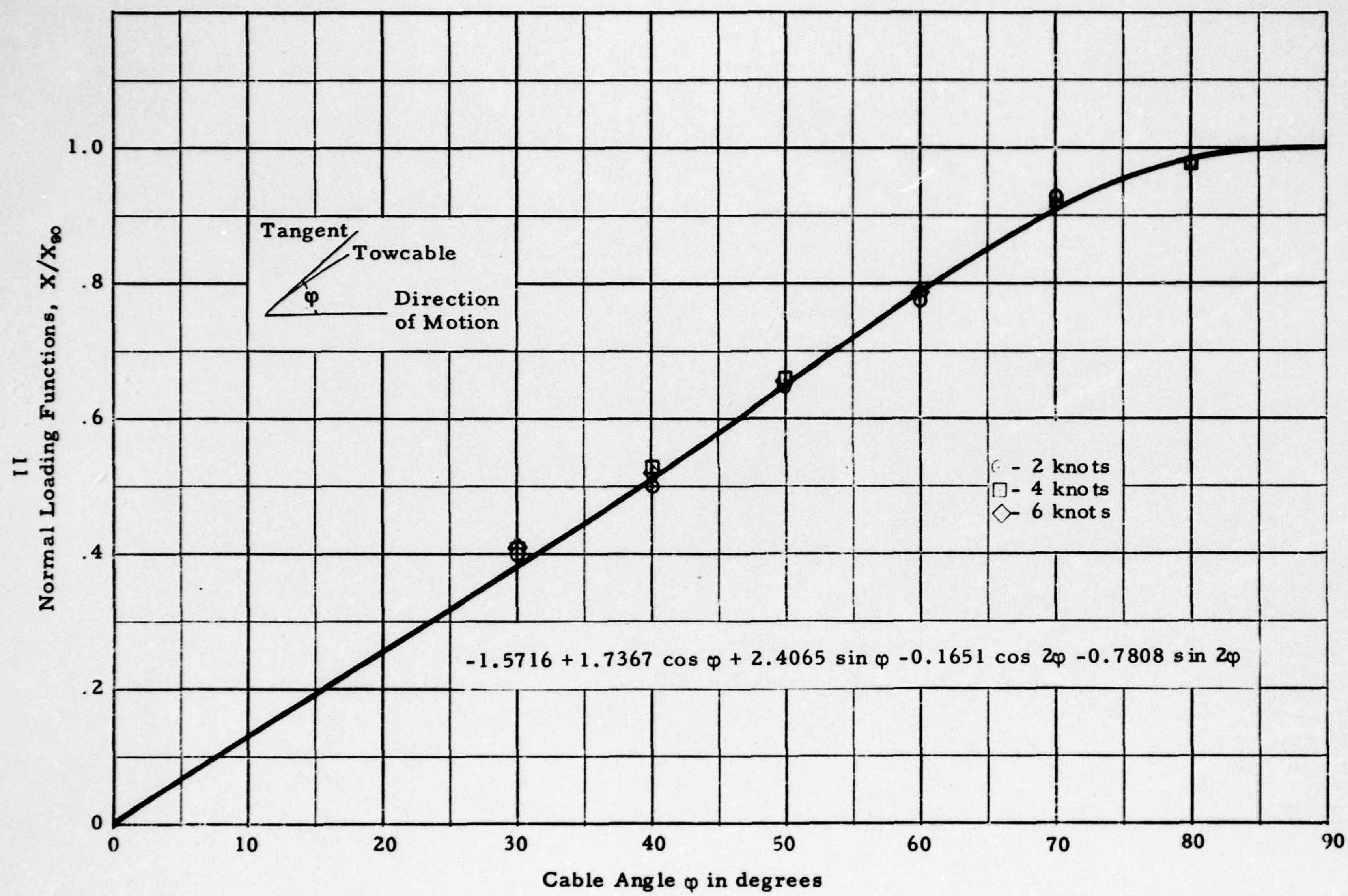

Figure 5 - Normal Loading Function as a Function of Cable Angle

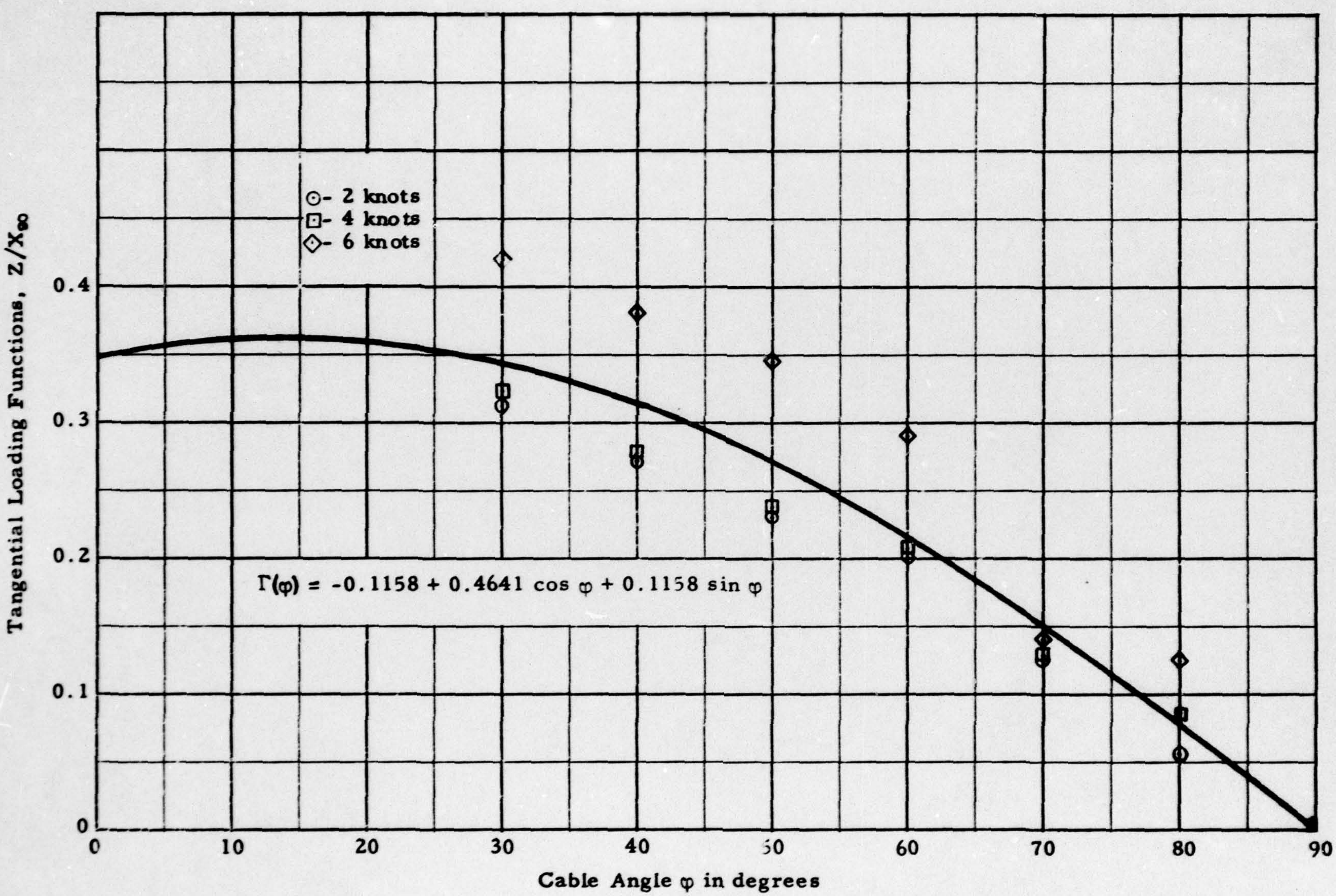

Figure 6 - Tangential Loading Function as a Function of Cable Angle

DRAG COEFFICIENT

The drag coefficient C_R and corresponding Reynolds number R_d were calculated for each speed using the following expressions:

$$C_R = \frac{R}{\frac{1}{2}\rho d V^2} \qquad [4]$$

and

$$R_d = \frac{Vd}{\nu} \qquad [5]$$

where

d is the fairing thickness,

R is the drag per unit length of cable when the cable is normal to stream and is equal to the slope $\frac{\Delta X}{\Delta s}$ of the linear force versus submergence plot at $\varphi = 90$ degrees ($R \equiv X_{90}$),

s is the distance along the cable (submergence),

V is the speed,

ρ is the mass density of fresh water at 70 degrees F, and

ν is the kinematic viscosity of fresh water at 70 degrees F.

The results of these computations are shown in Figure 7 as fairing drag coefficient as a function of Reynolds number.

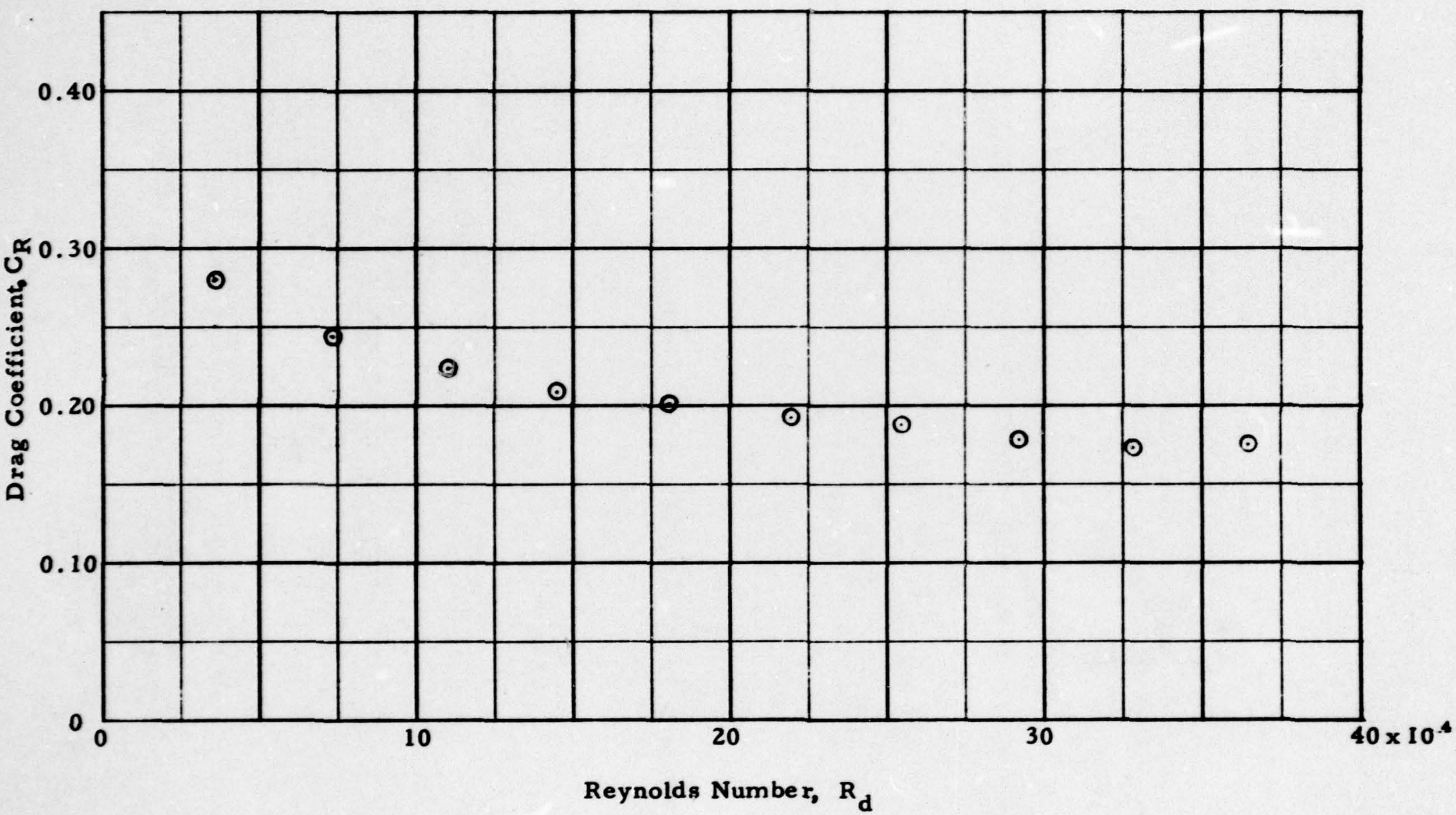

Figure 7 - Drag Coefficient Versus Reynolds Number

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